XP-008004114

Leakage detection systems by using Distributed Fiber Optical Temperature Measurement

Bernhard Vogel, Christian Cassens, Andrea Graupner, André Trostel

GESO Gesellschaft für Sensorik, geotechnischen Umweltschutz und mathematische Modellierung mbH Jena

Jena, Germany

ABSTRACT

A distributed fibre optical temperature sensing technique for different monitoring tasks, especially for leakage detection in oil and gas facilities, pipelines, underground storage sites, water constructions sites, mining and environmental industries is presented

1. THE DISTRIBUTED FIBER OPTICAL TEMPERATURE MEASUREMENT

1.1 Fundamentals of fiber optic temperature sensing

The distributed fiber optical temperature sensing is based on optical time - domain reflectometry (OTDR). A pulsed laser is coupled to the optical fiber which is the sensing element. The optical fiber laser is neodymium-doped and has a wavelength of 1064 nm, the pulse duration is 10 ns. The light is backscattered as the pulse propagates through the fiber owing to changes in density and composition as well as to molecular and bulk vibrations. A portion of the backscattered light is guided back to the source and is split off by the directional coupler to the receiver. The backscattered light includes the Rayleigh, Brillouin and Raman backscattering light. The Raman backscattering light is caused by thermally influenced molecular vibrations and can be used to obtain information about the temperature distribution along the fiber. The Raman backscattering light has two components: the Stokes and the Anti-Stokes components. The Stokes component is only weakly dependent on temperature, while the Anti-Stokes component shows a strong relation to temperature.

The basic principle of fiber optic temperature measurements, thus, consists in filtering the Stokes and the Anti-Stokes components out of the backscattering light. The ratio of the intensities of both components is calculated and transferred in temperature values using both the internal reference temperature of the equipment and an externally determined calibration function for the particular fiber type. Taking the ratio of the intensities of the Stokes and the Anti-Stokes components external influences such as changes of the light source or age effects of the optical fiber are eliminated.

The temperature is determined as an integral value for a short section of the optical fiber and the space coordinate is obtained from the travel time of the propagating light pulse. Therefore, it is possible to measure the temperature simultaneously along the entire length of the fiber. The space resolution at present is 1 m (optional 0.5 m or 0.25 m).The absolute temperature is determined using a calibration function which depends on the specific material properties of the optical fiber (geometry and chemical composition) and their temperature dependence. These properties can be different for different optical fibers. The calibration function must be determined for the individual optical fibers before the measurements are performed. The accuracy of the temperature measurements is 0.3 K, and a resolution up to 0.05 K can be reached. The available accuracy is controlled by the accuracy of the fiber-specific calibration function, whereas the available resolution and precision depend on the specific material properties of the used optical fiber.

The Raman backscattering intensity is integrated for a given fiber section (1 m, 0.5 m or 0.25 m, resp.). Thus, the measured backscattering intensity defines the integral temperature for this interval in contrast to standard temperature sensors which

Smart Structures and Materials 2001: Sensory Phenomena and Measurement Instrumentation for Smart Structures and Materials, Eric Udd, Daniele Inaudi, Editors, Proceedings of SPIE Vol. 4328 (2001) © 2001 SPIE · 0277-786X/01/$15.00

give the local temperature at the position of the sensor. Backscattering of light is a stochastic process, therefore, it is necessary to integrate the backscattering intensity for a given time interval. Taking a geometrical resolution of 1 m an integration time of 1 min is sufficient to minimize the stochastic noise. The integration time must be increased by a factor of 2 or 4 if the space resolution is increased to 0.5 m or 0.25 m, respectively. For a large fiber length (> 8 km) the optical absorption in the fiber decreases the available space and time resolution. The fiber optic temperature sensing system operates without any electronic circuits along the fiber.

The fundamentals of the measurement principle are shadowed in fig. 1:

$$I_a / I_s = \{(\nu_0 + \nu_k)^4 / (\nu_0 - \nu_k)^4\} \exp(-hc\nu_k / kT)$$

I_a - intensity of Anti-Stokes-component
I_s - intensity of Stokes-component
ν_0 - light wave number
ν_k - shift of light wave number
h - Planck action quantum
c - velocity of the light within the optical fibre
k - Boltzmann-constant
T - temperature

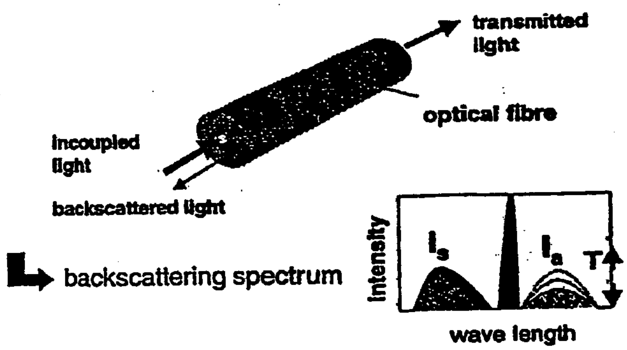


Fig. 1: Measurement Principle

1.2 Instrumentation of distributed fibre optical temperature sensing technique

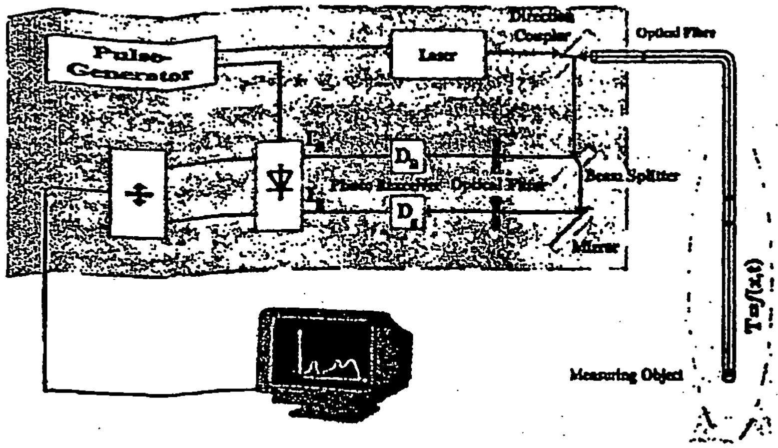
The measuring equipment consists on the measuring instrument (shadowed in fig. 2) including a computer for controlling and data acquisition and the fiber optic cable as the sensing element. Fig. 2 shows schematically the fiber optic temperature sensing instrumentation.

The fiber optic temperature sensing cable makes it possible to measure temperature in one, two or three dimensions. According to the problem the measuring object in fig. 2 can be power supply channels, supply pipes (gas, water), or objects with a two-dimensional or three-dimensional array configuration of the sensing cable (e.g. walls, rooms, containers, reservoirs, tanks, tunnels).

The measuring instrument can be installed in a control station or at any place in a building. Data transmission is possible. Already installed fiber optic cables (e.g. fiber optic cables for data transmission and communication) can be used for temperature sensing. This is of special advantage for the temperature survey of data communication lines in buildings (e.g. bankhouses).

Main characteristics of the fibre optical temperature sensing technique are the following:

1. Easy installation of an optical temperature sensing cable
2. No active electronic circuits along the cable
3. Long-term monitoring of the temperature
4. Temperature measurements can be repeated after any time interval
5. Use in corrosive environments



Resolution ranges for measuring lengths up to 30 km *):

- Spatial resolution ≥ 0.25 m *) (standard 1
- Temperature resolution ≤ 0.1 K *)
- Temperature accuracy better ± 0.3 K
- Temperature range -50°C ... +150°C
- High temperature range up to 250 °C

The data signed with *) depend on each other.

Fig. 2: Fiber optic temperature sensing instrumentation

1.3 The software

The obtained temperature data of the measuring object can be processed and visualized by adjusting softwa customer-specific problems. Typical cases are specific trigger or visualization software tools to record and su of measuring objects and its variations with time and space and software tools for a computer-aided leak detecti

Main Data:

- the software tools run under WIN 9x, WIN NT 4.0, Linux
- individual graphical user interfaces (GUI) can be integrated in all process control systems.

1.4 Fiber optic sensor cables

Special fiber optic temperature sensor cables can be developed and configured according to the technical and conditions of the individual application.

In all cable configurations optical fibers are used for temperature measurements. The fibers are stress-free int sensor cables.

Physical application limits are:

- maximum temperature at the fiber + 250 °C
- minimum temperature at the optical fiber -190 °C
- small mechanical and no direct chemical influence on the optical fiber

Different cable constructions:

- GESO®T-LN for underground installation along pipelines

  This cable type is developed especially for an underground installation along pipelines transport ting fl technical gases. The cable is positioned and fixed in the sand bed or directly at the pipeline and allow a detection and location of leakages of the pipelines.

- GESO®T-TS for the installation for indoor conditions

  This cable type is developed especially for the installation for indoor conditions. The sensor cable ha diameter and can be installed without any problems under plaster or wallpaper, in cable channels, in t the ceiling or floor of rooms..

- **GESO®T-TK combination cable telecommunication-leakage detection**

  This cable type is developed especially for a combined leak detection und data transmission at and in pipelines. The cable can be installed in the pipeline bed. Furthermore, it is possible to install the cable in existing pipeline systems (e.g. municipal or regional gas pipelines) even when they are in operation. Thus, using only one cable it is possible to combine leakage detection of pipelines with data transmission and telecommunication which has been proved for city or local communication networks.

- **GESO®T-TM for high mechanical load conditions**

  This cable type is developed especially for the leak detection under a high mechanical load (pressure, stress and strain). The cable can be installed free hanging in deep wells, along pipelines or at the upstream face of reservoir dams. The combination of a twofold plastic cover and a double-layer Kevlar-tension relief around a central optical fiber guaranties a high mechanical strength of the sensor cable.

- **GESO®T-TXM for extreme mechanical load conditions**

  This cable type is developed especially for the leak detection under extreme mechanical load conditions (pressure, stress and strain). The cable can be installed free hanging in deep wells, along pipelines or at the upstream face of reservoir dams. The combination of a tension relief steel cable with a plastic cover around a central optical fiber guaranties an extreme mechanical strength of the sensor cable.

- **GESO®T-TEHS for high voltage cables**

  This cable type is developed especially for the short circuit detection of power transmission cables. The optical temperature sensing fiber is integrated in at least one cable conductor of the power transmission cable. Using the temperature effect high voltage cables can be surveyed and short circuits can be detected and located.

- **Connecting cable type GESO®AK**

  This cable type is developed especially for connecting the temperature sensor cable with the measuring device. The cable is prefabricated with plug connectors.

2. THE LEAK DETECTION SYSTEM

2.1 Leakage detection of supply pipes

Leakages of supply pipes such as hot or freshwater, district heating pipes as well as gas pipes can be detected and localized by surveying the temperature variations with time along the pipes.

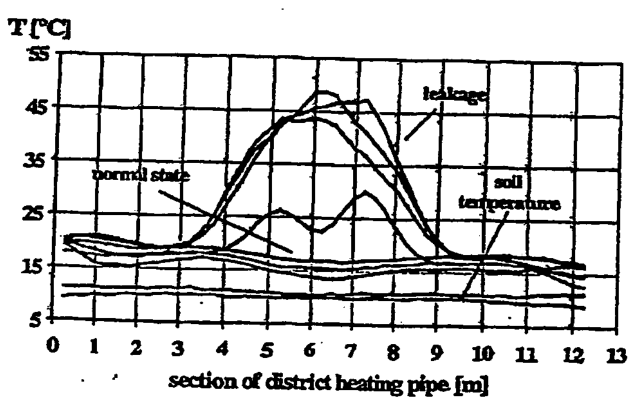


Fig. 3: Fiber optic temperature measurements along a district heating pipe

Fig. 3 gives as an example of the temperature anomaly around a leakage of a district heating pipe which is installed in the soil at a depth of about 1 m. The lower two curves give the temperature distribution in the soil.

The three curves with temperature values between 15 °C and 20 °C are typical for the „normal" state of the temperature around the pipe. The leakage of the pipe is indicated by a strong temperature increase.

Around a leakage of a gas pipe line a temperature decrease occurs due to the Joule-Thomson effect. For methane holds that the temperature decreases by 0.5 °C if the pressure decreases by 1 bar.

Table I gives an overview over the temperature effect for different media. In case of leakage of warm water, hot water/steam (e.g. district heating pipes) strong positive anomalies will occur. At leakages of gas pipes a negative temperature effect occurs due to the Joule-Thomson effect. Hot spots along power supply lines indicate damage and fire risk.

Medium	Temperature	Temperature effect
fresh water	8-10 °C	negative
warm water	50-60°C	positive
hot water / steam	100-120 °C	positive
gas	temperature decrease depends on the pressure decrease	negative
liquid gas	temperature decrease depends on the boiling heat	negative
power supply lines	hot spots	positive

Table 1: Temperature effects for different media

2.2. Two-dimensional fibre optic temperature measurements

The fiber optic temperature sensing cable can be installed in any configuration. Of special interest are temperature measurements in a plane (e.g. walls of any room or containment). In this case, the sensing cable is installed as a meander and fixed at the plane. Depending on the problem the distance between the cable sections can be some decimetres up to many meters. The cable position must be exactly known and can be integrated in any facility management or GIS-system. Fig. 4 gives the two-dimensional temperature distribution for an area with the dimensions 18 m x 14 m.

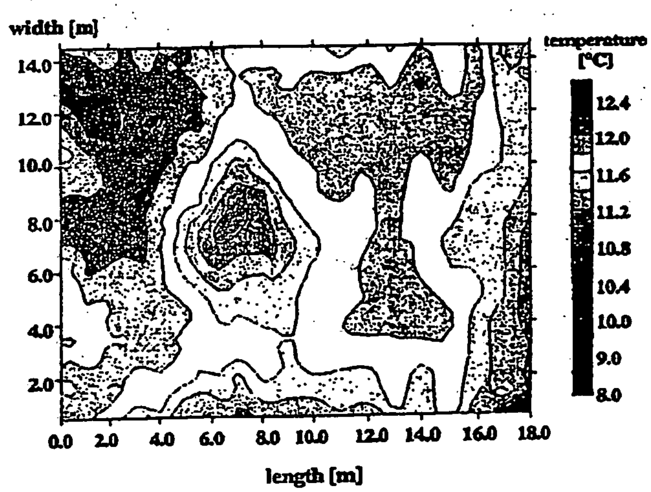


Fig. 4: 2-dimensional temperature distribution of a studied area with a leakage. (Measuring time: November)

After the installation of the cable the area was covered by a 0.8 m thick clay layer to study the effect of changing air temperature, artificial leakages, and the internal structure of the clay layer. The distances between the single cable section of the cable meander was 0.5 m. The temperature field shows significant anomalies which can be attributed to existing soil structures.

In the centre there is a strong negative anomaly indicating that in this area the temperature decreased within 24 h significantly.

These results show the new possibilities of two-dimensional temperature measurements for facility management systems in buildings and other structures such as:

- detection and localizisation of thermal bridges in buildings,
- detection and localization of damages of supply lines which are installed under plaster,
- optimization and control of air-conditioning and ventilation installations in rooms, buildings and other structures (e.g. public buildings, airports, museums).

The measuring data can be processed and represented on-line and any changes in time and space can be recorded.

3. PRACTICAL APPLICATIONS OF THE GESO LEAK DETECTION SYSTEM

3.1. Leak detection along high pressure gas as well as oil and product pipelines

Escapes of oil and gas due to leaks in underground pipelines are dangerous for the population and environment. Leaking oil contaminates soil and groundwater. Leaking gas can cause explosions and is harmful to vegetation and atmosphere. Furthermore, oil and gas leakages cause high economic losses. Therefore, it is necessary to monitor the pipeline using a system that is able to detect even small leaks with high spatial resolution. Fibre optic temperature sensing is predestined for this task. An optical sensor fibre, which is temperature sensitive on its entire length, is installed parallel to the pipeline to measure the temperature profile in the soil near the pipe. Leaking oil is seeping downwards and usually causes a temperature anomaly below the pipe. Leaking gas propagates along the pressure gradient - mainly upwards - and causes a temperature anomaly around the pipe due to the expansion of the gas (Joule-Thomson effect). Automatic comparison of the currently measured temperature profile with reference profiles (measured during normal operation) is an efficient and reliable method for leak detection and long-term monitoring of oil and gas pipelines. The sensor fibres can optionally be integrated into telecommunication cables.

Fig. 5 shows, for example, the results for a high pressure gas pipe line. The pipe was buried at a depth of about 1 m. Fiber optic temperature sensing cables were installed in different positions and distances from the pipe to study in detail the temperature field around the leakage. The upper curve in fig. 5 gives the soil temperature before the leakage. The lower curve gives the temperature distribution around the leakage for a leaking rate of 1 l/s. The temperature decrease in the soil is 4 °C, the cable was installed along the pipe in a 6 o'clock position.

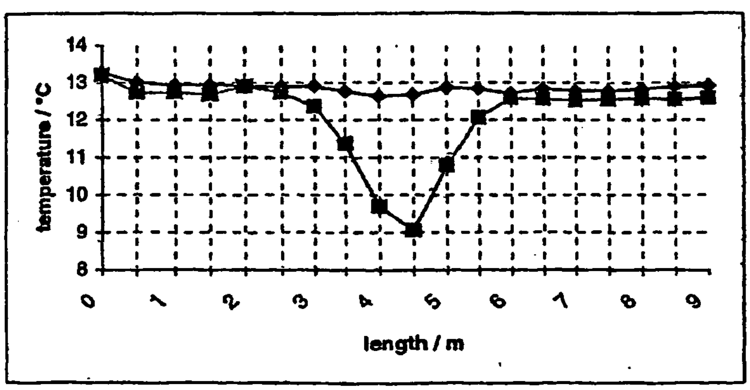


Fig. 5: Temperature distribution along a high pressure gas pipeline with a leakage rate of 1 l/s

3.2. Fibre optic temperature systems for long time monitoring of cavern storages for Oil and Gas

Aquifer and former oil and gas reservoirs are used as storages for natural gas. Caverns are used for storage of natural gas as well as mineral oil and fluid gas. Preparation, construction and management of such systems require a complex interdisciplinary work between engineers and scientists. In order to ensure smooth management as well as safety for human life and environment, those systems have to be monitored permanently. For the evaluation of the management, the monitoring of the temperature distribution and its temporal variation is necessary.

The fibre optic distributed temperature sensing now offers the possibility of monitoring the vertical temperature distribution on-line and over long periods of time in a borehole and a cavern at the same time. For the measurement mechanically robust and chemically inert fibre cables are used. The fibre cable is installed into the borehole and the borehole is sealed. The fibre cable may be installed at the borehole as well as outside the borehole attached at the casing. Once the fibre cable is installed, the monitoring process does not influence the management of the storage.

Temperature, besides pressure, is one of the most important parameters for the evaluation of cavern storages. In almost all thermodynamic relations, temperature is a necessary parameter. The various sections of cavern storage necessitate the knowledge of the local thermodynamic conditions that are significantly different in each section (for instance at the flux volume from the storage volume etc.). The dew point, vapour pressure etc. be may only determined if the exact distribution of temperature is known. Also chemical reactions depend on temperature. Using the fibre optic measurement it becomes possible to monitor the vertical temperature distribution at the borehole and the storage at the same time.

The storage management is not effected by the installation of the fibre cable. It is also possible to monitor the temperature under injection and exploitation condition.

It is even possible to measure the temperature distribution at a cavern during the flushing process. Because of the temperature gradient at the gas/brine interface the brine table can be detected and temporally monitored.

Also, the speed of the cavern flushing is dependent on the temperature because of the temperature depending solubility. During this process the gas has got the same temperature as its surrounding. The temperature of the solid phase is higher than the temperature of the water used for the flushing process (geothermal gradient 3°C/100m). The interface between fluid phase and gas phase can be detected by the change in temperature. Thus it is possible to monitor the brine table.

Advantages of fibre optic distributed temperature sensing for pore- and cavern storages:

- On-line monitoring of the vertical temperature distribution at the borehole and the storage at once.
- High spatial and temperature distribution: $\Delta x = 1m$ (optional 0.5m or 0.25m).
- Temperature ranges of -50°C up to +250°C, pressure range 75 MPa.
- No influence of the storage management due to measurement process.
- No electricity used for the measurement and therefore no risk of explosion.
- The period of lifetime of a fibre cable is at least 30 years.
- Embedding into existing computer aided monitoring network for on-line monitoring.
- Occasional monitoring in case of seasonal changes in heat load is possible.

3.3. Leakage detection in underground gas storage wells

Simultaneous temperature monitoring in storages before and after gas is stored enable the detection of leakages, especially broken sockets as well as flow processes behind the casing. The graph of the temperature differences of the temperature profile before and after a medium stored shows a leakage at the depth levels where negative temperature differences occur.

The Fig. 6 shows schematically the two possible kinds of a leak in a storage well:

- There are a leak only in the tubing.
- There are both the leak in the tubing and in the casing. The gas can escape duo to the leak into the surroundings.

In either case you can measure a high pressure in the space between the tubing and the casing. You can't discern it by using normal measurement equipment.

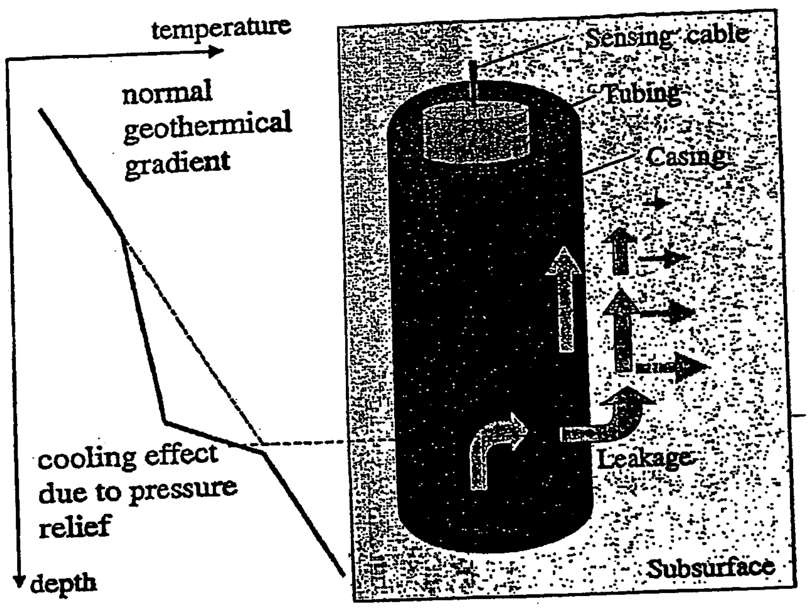


Fig. 6: The temperature anomaly measured by the fiber optic measurement system detects a leak

According to interpretation of a row of measurements with the GESO® system during different operating regimes of the storage (e.g. injection or withdraw of gas) you can discern the both kinds of a leak. This offers new possibilities for test and maintenance of gas storage facilities.

The GESO® system meets the following technical characteristics:

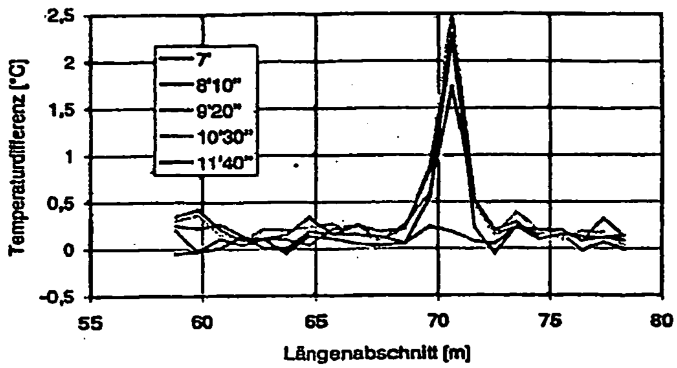
- measuring temperature range — up to 140 °C
- borehole depth — up to 3.500 m
- spatial resolution — 1,0 m
- max. working pressure — 310 bar
- independent of operating conditions of the storage
- all wire line tools are usable together with the GESO® cable

(for example pressure measurement tool, CCL, ...)

3.4. Leak detection in heating alignments

The importance of heat supply via municipal heating is increasing nowadays. Thus it is important to minimise heat lost on the way from the supplying factory to the customer. Heat pipelines consist of a pipe and an insulation. Radial heat loss is inevitable but the insulation can decrease the rate of heat loss significantly. In case of changes in the material of the insulation (for instance due to impact of moisture) the insulation properties changes significantly and high rates of heat loss occur. In connection with seasonal changes in heat load are often arising in spring and autumn. In case of leakages hot water withdraws from the pipeline and additional losses manifest. The decreasing pressure gradient at the pipeline network effects its steering properties. Therefore it is very important to detect even small leakages with small loss rates as soon as they occur. The fibre optic temperature monitoring offers new possibilities for monitoring and detecting heat losses at municipal heating alignments. The fibre optic cable is installed along the alignment and enables the possibility of permanent monitoring of the temperature along the pipeline and its surrounding. The monitored length might be up to 4 km long. In case of damage at the insulation or a leakage at the pipeline the temperature changes significantly, which can be detected using the distributed fibre optic temperature sensing. In case of pipelines at the subsurface the temperature is measured directly on the outside of the insulation.

At shaft alignments the fibre cable is located at the concrete floor of the shaft. Recent measurements have shown that even very small leakages (1 litre/h) can be detected (see also the following figure).



Example: Leakage rates of 1L/h can be detected and localized within 8 minutes (d=5cm)

Fig. 7: Sequence of temperature in case of leakage

The application of fibre optic temperature measurement for the monitoring of municipal heating alignments offers the following advantages:

- The fibre cable can be easily installed.
- High Detection capability (Temperature resolution <0.1K).
- High spatial resolution (typically 1m).
- On-line localisation of heat loss.
- Localisation of leakages.
- Monitoring of ramified networks with a length of up to 4km (at present time).
- Embedding into existing computer aided monitoring network for on-line monitoring.
- Occasional monitoring in case of seasonal changes in heat load is possible.
- The life time period of a fibre cable is at least 30 years.

4. OTHER INTERESTING APPLICATIONS OF THE DISTRIBUTED FIBER OPTICAL TEMPERATURE SENSING

4.1. Fibre optic temperature sensing for detection, localization and surveying of water seepage through dams and dikes

Reservoir dams and dikes along rivers and canals protect the surrounding areas. Therefore, it is highly important to detect anomalies of water seepage. Water percolates through a dam or dike along different paths. An increased water percolation occurs at leakages of sealing systems of dams and dikes and represents a high risk for the stability of a dam. A long-term survey has to detect and localize sections of dams with an increased water seepage. Also, changes of the water percolation with time are to be recorded. The temperature of percolating water is different from the temperature in the non-influenced subsoil or open drain systems. Therefore, temperature anomalies are found at locations of preferred seepage paths. Temperature is a natural tracer to detect water seepages. The temperature in the subsoil and in drains is strongly influenced by the daily or seasonal variations of the air temperature. A long-term survey of dams and dikes requires simultaneous temperature measurements over large dam sections with a high spatial resolution. The fibre optic temperature sensing method offers these possibilities. The fibre optical sensing cable can be installed in any configuration along the dam line as such as in fixed vertical or inclined boreholes in the dam construction. Installation in existing drain systems is an other configuration possibility. The best position depends on the concrete monitoring task. Thus, a temperature sensing method is now available to control and to survey sealing systems of dams and dikes over a long time period (>30 years).

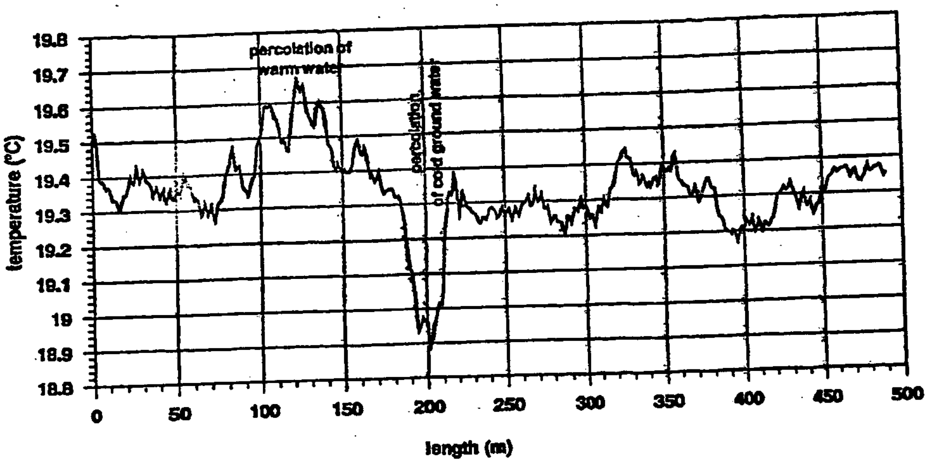


Fig. 8: Temperature distribution in a drain system of a dike with clear indications of percolating warm water from the canal and of cool ground water

Temperature surveying of dams and dikes using the fiber optic temperature sensing technique offers:

- long- term monitoring of water seepage through dams and dikes,
- simultaneous temperature measurements over long distances,
- detection of preferred seepage paths and of leakages,
- on-line-surveying of dams and dikes during times of strong water load and flood periods,
- temperature measurements in open drain systems and/or in the subsoil below the ground water level,
- detection and survey of the vertical profile of water seepage in dams and dikes using a fibre optic sensing cable installed in boreholes,
- the temperature data provide the base for risk assessment and for taking measures to stabilize and reconstruct dams.

4.2. Usability of the distributed fibre optical temperature sensing technology to monitor surface dams and embankment dams

Temperature conditions and thermal stresses caused by them are as important to gravity dams as the mechanical load owing to the hydrostatic force because these values make it possible to rate the strain behaviour and by that the stability of a massive dam. The DVWK-code of practice demands the installation of temperature sensors inside of at least three profiles with five control points each within the dam. In contrast to the conventional punctual temperature sensing technology, the fibre optical temperature sensing technology opens up many new possibilities at monitoring dams.

A steady temperature profile with a high spatial resolution output (1m) is received along the installed spectrometer cable using the fibre optical temperature sensing technique.

Sensitive areas of the embankment can be purposively monitored because of the manifold variants of arrangement of the spectrometer cable, and the accuracy of the incoming parameters for static calculations is also decisively increased.

Moreover this technology registers and locates leakages not only within the massive dam but also in the joints and in the surface sealing.

4.3. Fibre optic temperature sensing opens new possibilities for long-term monitoring and surveying of ground water levels and water quality levels

Ground water is one of the most important raw materials and of vital interest. Infiltration of water or other fluids originating from elsewhere frequently have a different temperature and therefore influence the temperature of the ground water locally along the flow paths. Such water can be contaminated or infiltrated from rivers and lakes. Also variations of the ground water table can be surveyed by temperature measurements. Furthermore, wetting of the ground can induce biological processes and chemical reactions, most of those are exothermal. By this way the temperature can be used as a sensitive tracer for various subsurface processes related to ground water or the substrate's water saturation. By measuring the temperature distribution and its temporal variation an efficient surveying system can be set up. The distributed fibre optical

temperature sensing technique - using fibre optic sensor cables - allows the installation of a long-term monitoring system for ground water sources and water related subsurface processes. The durability of the sensor cables is larger than 30 years.

4.4. Fibre optic temperature sensing opens new possibilities for long-term surveying and risk assessment of waste deposits and former waste disposal sites

The policy and legal regulations for protecting groundwater and natural environment require a long-term surveying of waste disposal sites during the active phase of depositing material and after closing the deposit. The temperature distribution and its changes with time within a waste deposit and at the base of a waste deposit are key parameters for the risk assessment of waste disposal sites. Heat is produced by biological and chemical reactions. Chemical reactions in lags and ashes from industrial waste disposal sites and in sulphidic material from overburden dumps produce a large amount of heat. Therefore, long-term measurements of the temperature changes with time in a plane or volume are an efficient method for surveying waste disposal sites and industrial dumps. The fibre optic temperature sensing technique opens the possibility for a long-term survey. The temperature field within an active or former waste disposal site can be measured over a time period > 30 years using a permanently installed fibre optic temperature sensing cable.

This fibre optical monitoring system can be used not only for detecting heating areas but also for detecting and localization of leakage zones in sealing layers of the waste deposit.

4.5. Fibre optical temperature measurement for Computer Aided Facility Management (CAFM)

The linear sensor cable can be up to several kilometres long and can easily be attached to a cable trench in a building for instance. Electronic sensors attached along the fibre cable for measurement are not needed.
The gauge delivers the data in form of Temperature/Location sets.
This data is not very useful because it describes the temperature distribution along the fibre cable and is not yet connected to the situation at the building structure
However, if the data is connected to a digital map derived from a Facility Management Solution it becomes possible to connect the temperature data to 2D- or 3D – coordinates and it is even possible to connect the data to defined spaces.

Thus it becomes possible to interpret the data using the manifold presentation facilities of a CAFM-System:

- 2D colour coded temperature distribution maps of defined spaces,
- Temperature values at defined locations,

This monitoring system also offers a permanent comparison between the monitored data and limits of the temperature range for steering processes. In case of critical situations security measures can be taken automatically. For the person running the structure it is possible to control and steer online the evacuation according to the situation in the building.

5. CONCLUSIONS

We have presented new possibilities to use the distributed fiber optical temperature sensing technique for different monitoring tasks, especially for leakage detection in oil and gas facilities, pipelines underground storage sites, water constructions sites, mining and environmental industries. Even small leaks, so called micro leaks, can be detected and pinpointed with high precision within a short period of time. Due to the high sensitivity, leaks can already be detected when they come into being. By a special algorithm it is possible to run the system automatically, including leak recognition and pinpointing. Any software system can communicate with the standard interface of the gauge.

Practical experiences showed, that the technique can be used under field conditions. It is of special advantage that the fiber optic sensing cable can be installed permanently even under conditions where standard thermal probes cannot be used.

REFERENCES

[1] M. Kasch, E. Hurtig, S. Großwig, P. Schubart, "Leak detection and Online Surveying at Underground Gas Pipelines Using Fibre Optic Temperature Sensing", OIL GAS – European Magazine, 3'97, pp. 17-21

[2] S. Großwig, Tetsuo Nagai, Wu Zhiguang, "Dam & Dike Monitoring with help of Distributed Fibre Optic Temperature Sensing Technique", '99 International Conference on Dam Safety and Monitoring", Oct. 19-22 1999, China

[3] E. Hurtig, S. Großwig, K. Kühn, „ Distributed Fibre Optic Temperature Sensing: A New Tool for Long-Term & Short-Term Temperature Monitoring in Boreholes", Energy Sources – Journal of Extraction, Conversion and the Environment, Vol. 19, 1'97, pp. 55-62